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Carlson et al.

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(54) **HIGH PRECISION HAND-HELD
ENGINEERING SURVEY/POSITION DATA
COLLECTOR TABLET COMPUTER**

G01S 19/32; G01S 19/40–19/44; G01S 19/51;
G01S 5/04; G01S 5/14
See application file for complete search history.

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(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 524 days.

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Related U.S. Application Data

(63) Continuation-in-part of application No. 12/826,056,
filed on Jun. 29, 2010, now abandoned.

(57) **ABSTRACT**

(60) Provisional application No. 61/539,321, filed on Sep.
26, 2011, provisional application No. 61/222,544,
filed on Jul. 2, 2009.

A self-contained, hand-held, wireless engineering survey
data collection system and method includes a survey data
collector ruggedized to MIL-STD-810G, having a housing
with a hand-held, tablet, form factor, and a processor,
memory module, data storage, power source, and a full per-
sonal computer operating system. A user interface is sup-
ported by the housing and communicably coupled to the
processor. A survey module configures the processor,
memory module, data storage, and user interface to capture
and store engineering survey data. Communications ports
enable communication with peripheral devices. A survey-
grade GNSS module configured for positioning accuracy
within a margin of error of 3 cm, is supported by the housing
and communicably coupleable to the processor. An internal
GNSS antenna is supported by the housing and communica-
bly coupled to the GNSS module. The survey data collector is
thus configured to capture engineering survey data including
position data generated by the GNSS module.

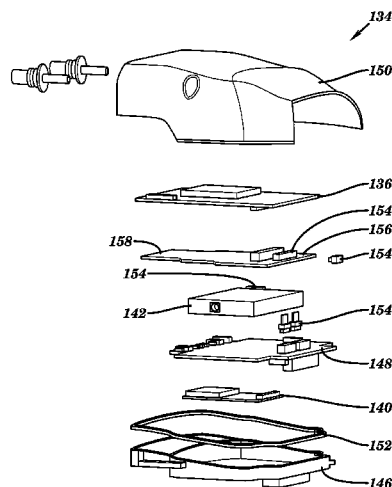
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G01S 19/42 (2010.01)

(Continued)

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CPC **G01C 15/00** (2013.01); **G01S 19/14**
(2013.01); **G06F 1/1656** (2013.01); **G06F**
1/1684 (2013.01); **G01D 9/005** (2013.01);
G01S 19/35 (2013.01)

(58) **Field of Classification Search**
CPC G01C 15/00; G06F 1/1656; G06F 1/1684;
G01S 19/05; G01S 19/07; G01S 19/13;

20 Claims, 7 Drawing Sheets



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G01S 19/35 (2010.01)
G01D 9/00 (2006.01)

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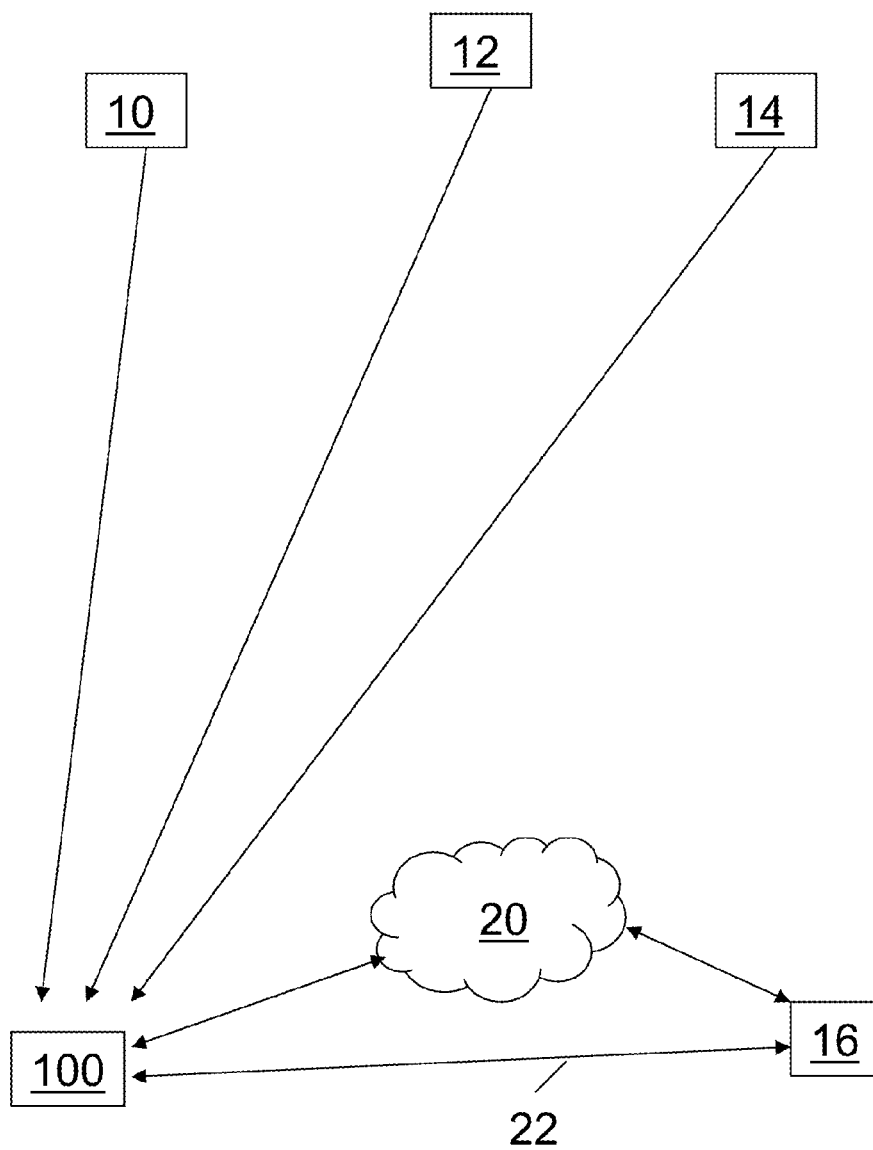


Fig. 1A

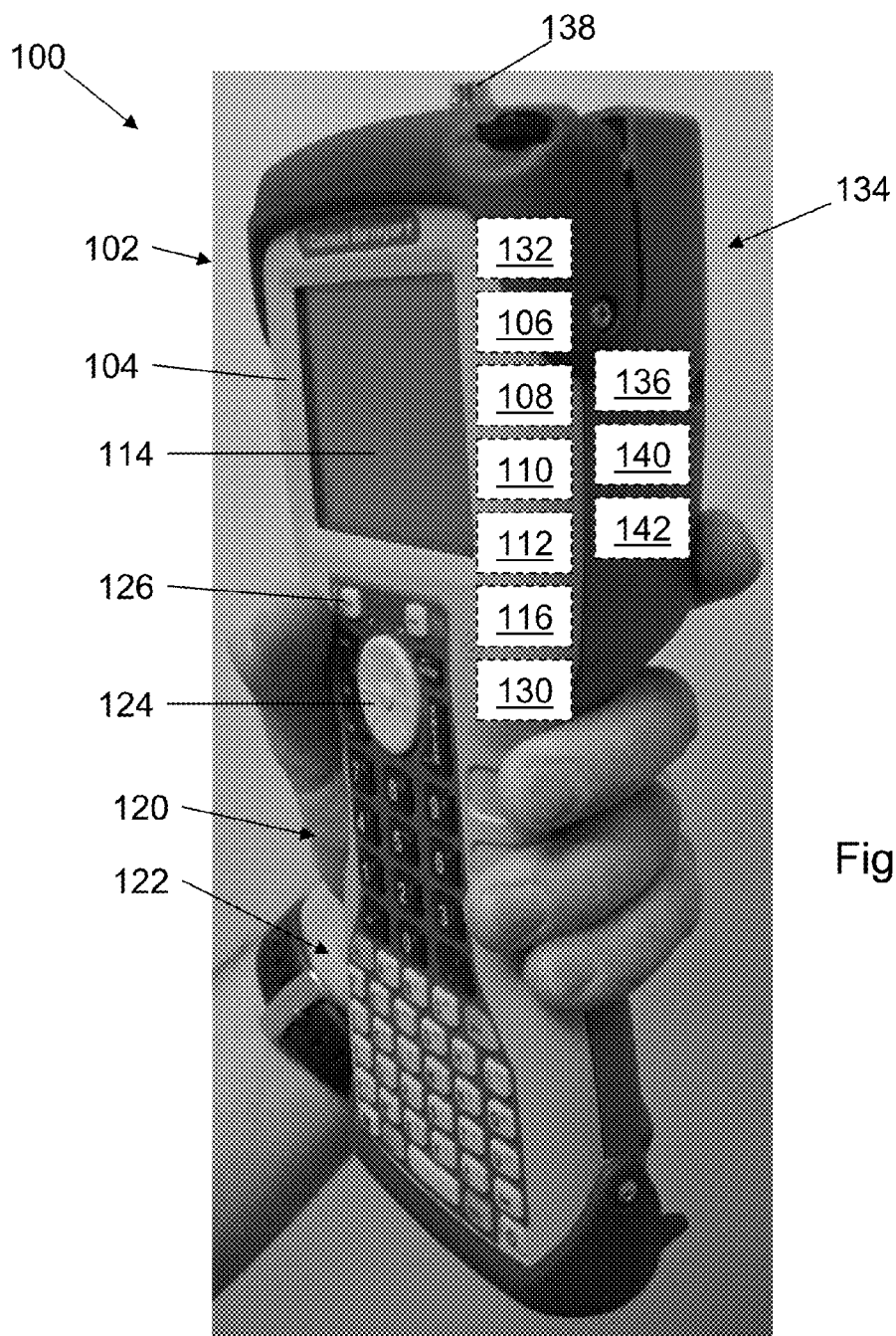


Fig. 1B

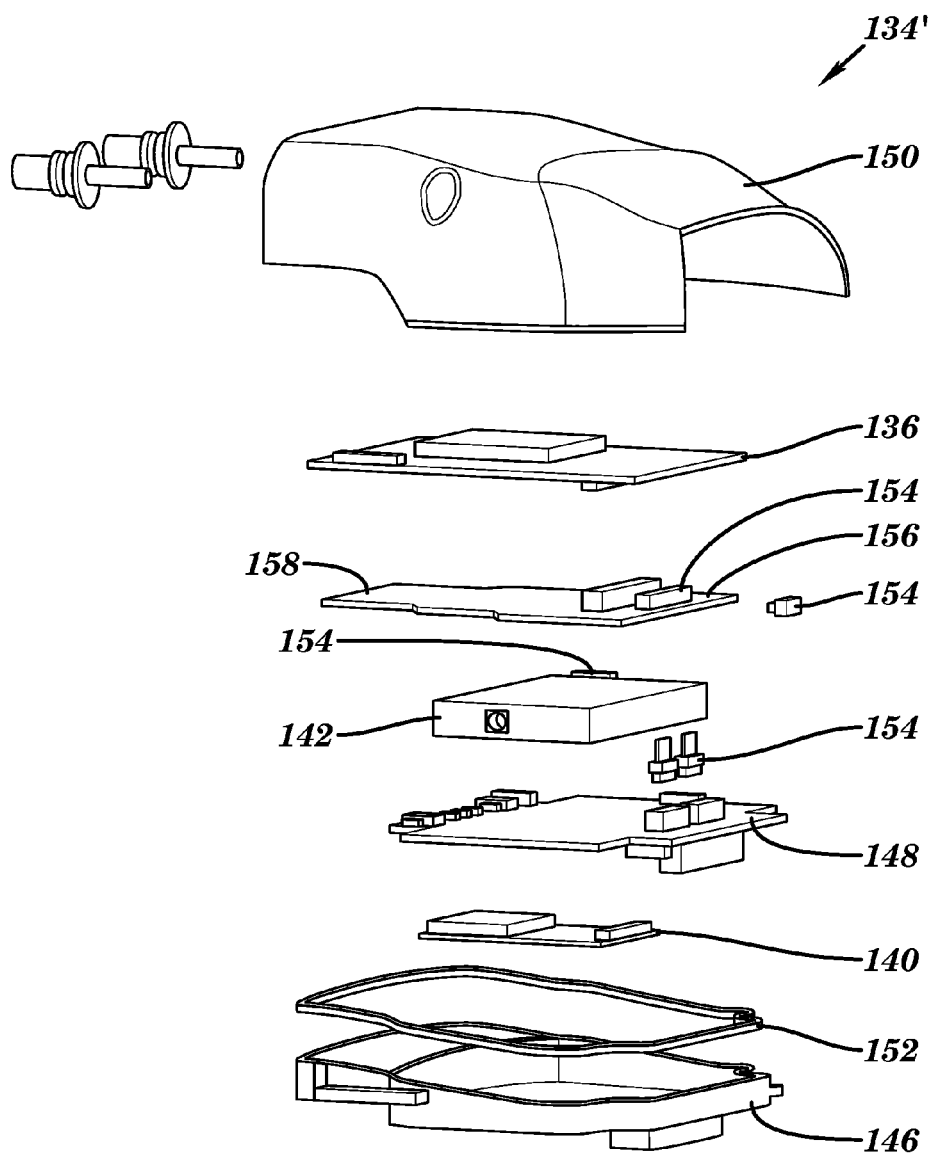


FIG. 2

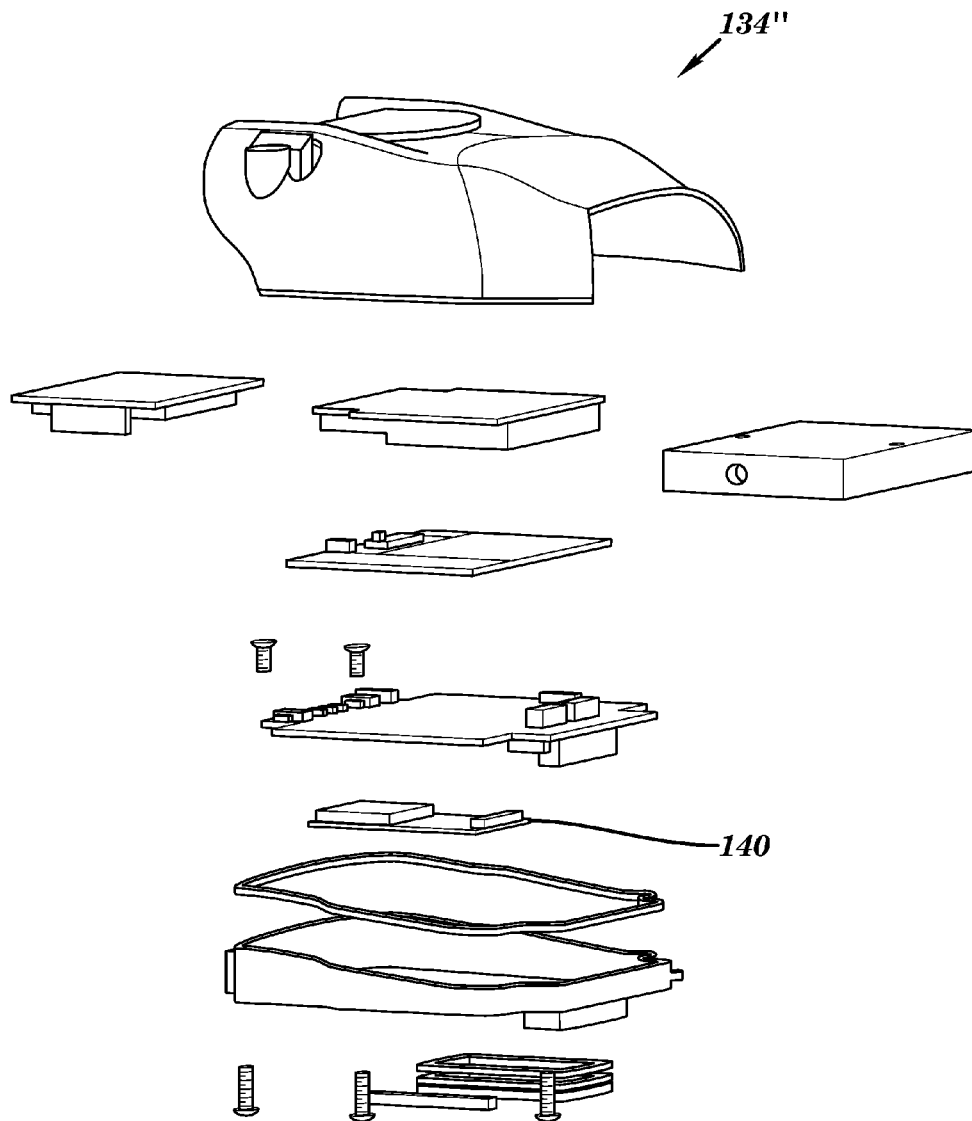


FIG. 3

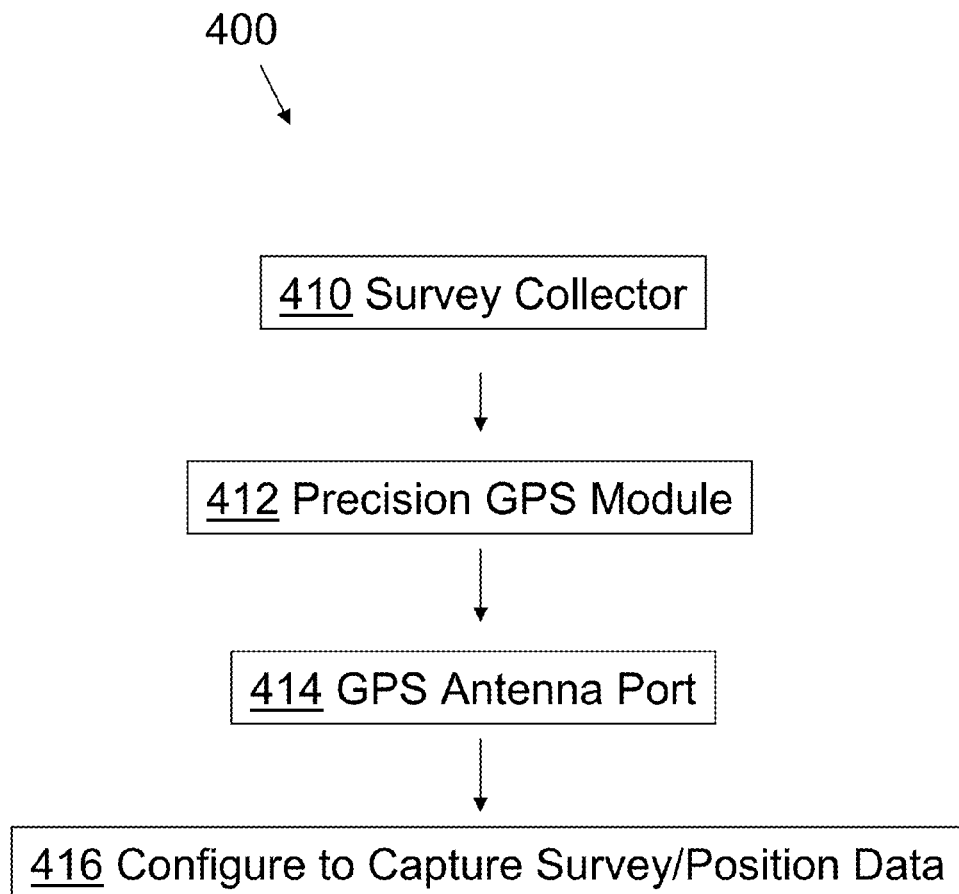


Fig. 4

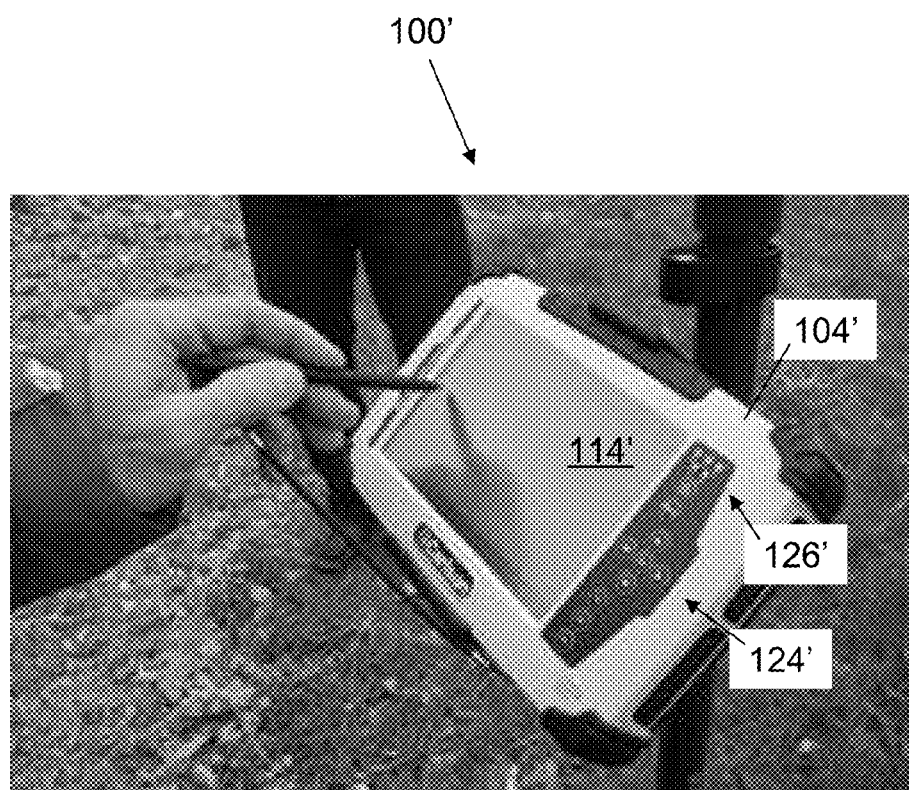


Fig. 5

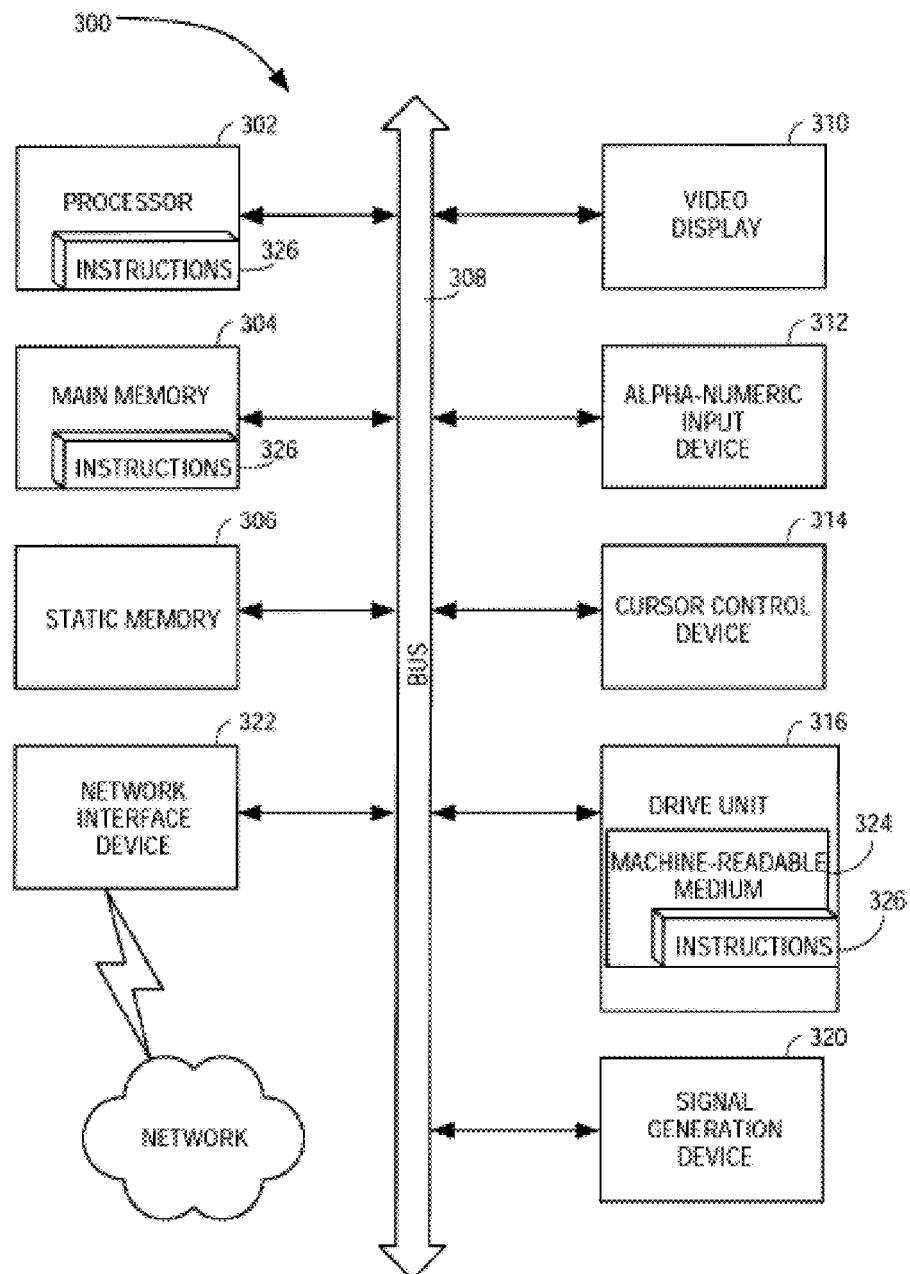


Fig. 6

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HIGH PRECISION HAND-HELD ENGINEERING SURVEY/POSITION DATA COLLECTOR TABLET COMPUTER

RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application Ser. No. 61/539,321, entitled Ruggedized Tablet RTK GNSS Survey System, filed on Sep. 26, 2011, the contents of which are incorporated herein by reference in their entirety for all purposes. This application is also a Continuation-In-Part of U.S. patent application Ser. No. 12/826,056, entitled High Precision Hand-Held Engineering Survey/Position Data Collector, filed on Jun. 29, 2010 now abandoned, which itself claims the benefit of U.S. Provisional Application Ser. No. 61/222,544, entitled High-Precision GPS Expansion Pack for Handheld Computer, filed on Jul. 2, 2009, the contents all of which are incorporated herein by reference in their entirety for all purposes.

BACKGROUND

1. Technical Field

This invention relates to engineering surveying and data collection, and more particularly to a ruggedized hand held data collector capable of providing high precision, survey-grade GPS positioning, e.g., with accuracy to within 3 centimeters, while providing various alternate means of wireless communication.

2. Background Information

Throughout this application, various publications, patents and published patent applications are referred to by an identifying citation. The disclosures of the publications, patents and published patent applications referenced in this application are hereby incorporated by reference into the present disclosure.

High precision GPS (Global Positioning Satellite) receivers are commonly used in the surveying and construction industries. However, devices using these high precision GPS receivers have tended to be cumbersome and not well integrated for these industries. For example, users in these industries were required to carry a GPS receiver box in a backpack and move about a survey/construction site with a GPS antenna on a pole, and a data collector, with cables connecting the various components. Later, equipment manufacturers began to place the GPS receiver box on the pole, often mounted halfway up the pole below the antenna, sometimes integrated with the antenna. This was generally considered to be an improvement, but the pole tended to be top-heavy. Moreover, while hand-held GPS devices are available, such devices generally only provide low accuracy, e.g., 3-6 foot accuracy in real-time, while accuracy within about 3 cm or less is desired for surveying/construction applications. These conventional low precision devices also tend to be single purpose devices and/or consumer grade devices which are generally unsuitable for use in an engineering surveying environment where they are expected to be subjected to generally rough handling and potentially severe environmental conditions.

Users must typically carry additional devices, such as two-way radios, cell phones, and internet connectable devices for communication and data transfer. The need for multiple devices is often exacerbated by the different competing formats/protocols that are in use. For example, for positioning, both the GPS (Global Positioning Satellite) system operated by the U.S., and the GLONASS (Global Navigation Satellite System) operated by Russia, may be used, which typically

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requires mutually distinct receivers. Similarly, conventional point to point two-way radio may be needed for voice communication in areas lacking cellular coverage, while cellular communication may be used in other locales. Data transfer may require yet additional formats/protocols, including 802.11x and/or cellular/3G, etc., depending on the installed base of legacy equipment currently in use by a particular user/organization.

Thus, a need exists for a single device capable of addressing one or more of the aforementioned unresolved issues.

SUMMARY

In one aspect of the invention, a self-contained, hand-held, wireless engineering survey data collection system includes a survey data collector having a housing with a hand-held form factor, and a processor, memory module, data storage, and power source disposed within the housing. A user interface including input and output devices is supported by the housing and communicably coupled to the processor. A survey module including computer readable instructions disposed in a non-transitory computer readable medium, configures the processor, memory module, data storage, and user interface to capture and store engineering survey data. A plurality of communications ports are configured for communicating with peripheral devices. The survey data collector is ruggedized to MIL-STD-810F. In addition, a survey-grade GPS module configured for positioning accuracy within a margin of error of 3 cm, is supported by the housing and communicably couplable to the processor. A GPS antenna port is supported by the housing and communicably couplable to the GPS module. The survey data collector is thus configured to capture engineering survey data including position data generated by the GPS module.

In another aspect of the invention, a method of fabricating a self-contained, hand-held, wireless engineering survey data collection system, includes providing a survey data collector having a housing with a hand-held form factor; a processor, memory module, data storage, and power source disposed within the housing; and a user interface including input and output devices supported by the housing and communicably coupled to the processor. A survey module including computer readable instructions is disposed in a non-transitory computer readable medium, for configuring the processor, memory module, data storage, and user interface to capture and store engineering survey data. A plurality of communications ports are configured for communicating with peripheral devices, and the survey data collector is ruggedized to MIL-STD-810F. A survey-grade GPS module configured for positioning accuracy within a margin of error of 3 cm is supported with the housing and is configured to be communicably couplable to the processor. A GPS antenna port is supported with the housing and configured to be communicably couplable to the GPS module. The survey data collector is thus configured to capture engineering survey data including position data generated by the GPS module.

The features and advantages described herein are not all-inclusive and, in particular, many additional features and advantages will be apparent to one of ordinary skill in the art in view of the drawings, specification, and claims. Moreover, it should be noted that the language used in the specification has been principally selected for readability and instructional purposes, and not to limit the scope of the inventive subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements and in which:

FIG. 1A is a schematic diagram of one embodiment of a system of the present invention in a representative application;

FIG. 1B is a perspective view of an embodiment of the system of FIG. 1A, with various optional and/or internal components shown schematically in phantom;

FIG. 2 is an exploded view of an alternate embodiment of an expansion module usable with the system of FIGS. 1A and 1B;

FIG. 3 is a view similar to that of FIG. 2, of another alternate embodiment of an expansion module usable with the system of FIGS. 1A and 1B;

FIG. 4 is a flow chart of an exemplary method in accordance with an embodiment of the present invention;

FIG. 5 is a view similar to that of FIG. 1B, of an alternate embodiment of the present invention; and

FIG. 6 is a block diagram of one embodiment of a computer system usable in various embodiments of the present invention.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration, specific embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized. It is also to be understood that structural, procedural and system changes may be made without departing from the spirit and scope of the present invention. In addition, well-known structures, circuits and techniques have not been shown in detail in order not to obscure the understanding of this description. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims and their equivalents.

TERMINOLOGY

Where used in this disclosure, the term “computer” is meant to encompass a workstation, personal computer, personal digital assistant (PDA), wireless telephone, or any other suitable computing device including a processor, a computer readable medium upon which computer readable program code (including instructions and/or data) may be disposed, and a user interface. Terms such as “component,” “module,” “control components/devices,” and the like are intended to refer to a computer-related entity, either hardware, a combination of hardware and software, software, or software in execution. For example, a component may be, but is not limited to being, a process running on a processor, a processor, an object, an executable, a thread of execution, a program, and a computer. By way of illustration, both an application running on a server and the server (or control related devices) can be components. One or more components may reside within a process and/or thread of execution and a component may be localized on one computer and/or distributed between two or more computers or control devices. The terms “real-time” and “on-demand” refer to sensing and responding to external events nearly simultaneously (e.g., within milliseconds or microseconds) with their occurrence, or without intentional delay, given the processing limitations of the system and the time required to accurately respond to the inputs. The term GPS or Global Positioning Satellite, is used for convenience to refer to substantially any system capable of determining three-dimensional geographical position coordi-

nates with survey-grade precision (to within 3 cm or less) including the aforementioned GLONASS system or any other system currently existing or developed in the future, capable of providing such high precision positioning, with or without orbiting satellites. For example, it is envisioned that such a future system may include a cellular or WiFi based system capable of determining position based on triangulation, or trilateration, etc., from multiple cell towers or WiFi sites, etc. Programming Languages

The systems and methods embodying the present invention can be programmed in any suitable language and technology, such as, but not limited to: C++; Visual Basic; Java; VBScript; Jscript; BCMAScript; DHTML; XML and CGI. Alternative versions may be developed using other programming languages including, Hypertext Markup Language (HTML), Active ServerPages (ASP) and Javascript. Any suitable database technology can be employed, such as, but not limited to, Microsoft SQL Server or IBM AS 400.

Embodiments of the present invention include a wireless engineering survey data collection system in the form of a ruggedized handheld computer configured for engineering survey data collection, wireless connectivity via multiple alternative formats/protocols, and high precision, survey-grade positioning data capture via multiple formats/protocols. These embodiments are thus configured for use with Real Time (RTK) GNSS (Global Navigation Satellite System such as GPS or GLONASS) and Total Stations with in-field coordinate geometry.

Turning to FIG. 1A, a data collection system **100** of the present invention is provided with multiple channels of communication, including receipt of signals from a series of navigation satellites **10**, **12**, **14**, etc., and cellular communication to a Total Station or other third party **16** via a network such as a cellular network and/or internet **20**. System **100** may also communicate directly with third party **16** via a point-to-point (e.g., radio) communication as shown at **22**.

Turning to FIG. 1B, an exemplary engineering survey data collection system **100** is shown. This system **100** includes a survey data collector **102** in the form of a housing **104** having a hand-held form factor. A processor **106**, memory module **108**, data storage/static memory **110**, and power source (e.g., rechargeable battery or supercapacitor) **112**, all shown schematically in phantom, are disposed within the housing **104**.

The data collector **102** also includes a user interface including input and output devices supported by the housing and communicably coupled to the processor **106**. In particular embodiments, the user interface includes a screen **114**, which may take the form of a touchscreen configured for enabling both input and output. Moreover, in particular embodiments the user interface is configured for operation with a gloved hand. In this regard, the screen **114** may take the form of a conventional resistive touchscreen which is not dependent on the capacitance provided by an ungloved finger. Optionally, the user interface may include a voice activation module **116** (shown schematically in phantom), which in combination with an integral speaker and microphone (not shown), is capable of receiving user input in the form of voice commands, and/or providing audible output. The voice activation module may operate independently of, or in combination with, screen **114**.

As also shown, in particular embodiments, the user interface may include a numeric keypad **120** and/or an alphabetic keypad **122**. As shown, keypads **120** and **122** may be distinct from one another, such as to facilitate operation with a gloved hand. In addition, or as an alternative, keypads **120** and **122** may be displayed on demand by the screen **114**. The user

interface may include any number of additional optional elements such as a navigation pad **124** and/or dedicated function keys **126**.

Although not required, in particular embodiments, the numeric keypad **120**, the alphabetic keypad **122**, and the screen **114** are all separate from one another as shown. Moreover, as mentioned above, the keypads **120**, **122**, and the navigation pad **124** may all be configured, e.g., sized, shaped and sufficiently spaced from one another as shown, for operation with a gloved hand.

A survey module **130**, e.g., in the form of computer readable instructions disposed in a non-transitory computer readable medium such as static memory **110**, is provided for configuring the processor **106**, memory module **108**, data storage **110**, and user interface to capture and store engineering survey data. In a representative embodiment, survey module **130** (shown schematically in phantom) may include the Carlson SurvCE GPS software application available from Carlson Software, Inc., (Maysville, Ky.) the Assignee of the present application.

As a further option, one or more communication ports **132**, also shown schematically in phantom, may be provided for enabling the data collector **102** to communicate with peripheral devices. For example, ports **132** may take the form of one or more conventional wireless modules/processors configured for Bluetooth and/or WiFi (802.11x) communication.

In the various embodiments described hereinabove, including any of the optional variations thereof, the housing **104** may be water and dust resistant to NEMA (National Association of Electrical Manufacturers) IP67 standards, while the entire data collector **102**, including housing **104**, may be ruggedized to meet one or more of the test methods of United States Military Standard MIL-STD-810F (U.S. Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests), e.g., pertaining to Contamination by Fluids, Shock, Humidity, Solar Radiation, High Temperature, Low Temperature, etc.

As also shown, system **100** includes a module **134**, which as shown, may take the form of a modular expansion pack supported by the housing and communicably couplable to the processor **106**. In particular embodiments, the expansion pack **134** houses a survey-grade GPS receiver **136**, e.g., configured for positioning accuracy within a margin of error of 3 cm or less. Optionally, the GPS module includes a multiple protocol/frequency receiver, e.g., to operate with either the U.S. GPS system, or substantially any other positioning system such as the aforementioned GLONASS Russian system, or other terrestrial geolocation systems. A GPS antenna port **138** may also be supported by the housing and communicably couplable to the GPS module, for connection to a conventional external GPS antenna (not shown). The various embodiments of the data collector **102** as described herein are thus configured to capture engineering survey data including position data generated by the GPS module.

In particular embodiments, the expansion pack **134** is configured for being selectively fastened to housing **102** when desired, and then removed from the housing **102** when not in use. However, it should be recognized that pack **134** may be fabricated as an integral, non-removable portion of the housing **104**. As will be discussed in greater detail hereinbelow, the expansion pack **134** may be provided with a range of additional features, to enable the data collector **102** to be customized for individual users. For example, in some embodiments, the module **134** may be provided with a cellular transceiver **140**, such as to provide the data collector **102** with Internet connectivity and/or wireless voice communica-

tion. In addition, or as an alternative, module **134** may be provided with a point-to-point audio transceiver **142**, such as a spread spectrum audio transceiver to permit wireless radio communication in areas not covered by cellular networks. The system **100** may be provided with any number of additional features common to conventional survey equipment, such as a tripod hook, wrist strap, battery charger, etc. (not shown).

Embodiments shown and described herein thus provide a self-contained, hand-held, wireless engineering survey data collection system **100**, which includes a removable, modular, expansion pack, for quick modification, in a plug-and-play manner to add or subtract functionality as needed for different applications. This approach provides a unique combination of GPS, computer, software, and multiple channel communication, in a hand-held form factor, while providing substantially the same GPS performance accuracy as other larger scale single-function survey-grade GPS receivers.

In exemplary embodiments, the data collector **102** may include a PDA or other handheld computer, modified in accordance with the teachings of the present invention. This computer may run the Windows CE™ or Windows Mobile™ operating systems (Microsoft Corporation, Redmond, Wash.), or substantially any other suitable operating system such as the Palm OS (Palm, Inc., Sunnyvale, Calif.), or Android (Google, Inc.) operating system, etc.

Particular embodiments, such as shown in FIG. 1B, include a ruggedized hand-held computer known as the Carlson Explorer 600+, commercially available from Carlson Software, Inc., which is configured to receive a modular expansion pack **134** including a GPS module, e.g., plugged into the back thereof, along with a relatively lightweight GPS antenna. The modular expansion pack may also include a radio module, such as a cellular telephone module as discussed above, to provide an internet link to GPS base stations and/or to office locations for data backup and transfer, all in a single, hand-held enclosure.

Thus, particular exemplary embodiments of the present invention provide a compact, high accuracy (to 3 cm or less), GPS enabled hand held computer that is linkable to the internet, for land surveying and construction positioning applications.

These embodiments may thus provide:

1. Removable, modular expansion pack.
2. Dual frequency GPS with positioning accuracy to within 3 cm.
3. Internet connection based on internal GSM/GPRS.
4. Internet GPS base station connection authentication via TCP Relay.
5. Radio for point-to-point communication.

It will be evident, however, to one skilled in the art that the present invention may be practiced without these specific details.

Turning now to FIGS. 2 and 3, two different exemplary modular expansion pack modules for the handheld data collector **102** are shown: a larger size module shown at **134'** in FIG. 2, and a smaller module shown as **134"** in FIG. 3. One will recognize that a primary difference between the larger and smaller packs is the interior space available for various components. As shown, the expansion packs have been configured to permit the installation of a variety of different electronics modules. For example, the large expansion pack **134'** is large enough to fit a survey-grade GPS receiver **136** (e.g., a Septentrio or Novatel GPS receiver board) in addition to cellular and radio modules **140**, **142**, while the smaller pack **134"** may be configured to contain any two of the modules **136**, **140**, **142**, such as a GPS receiver **136** and either a cellular

or radio module **140**, **142**. Any desired combination of these modules may be provided, including, if desired, the use of both a cellular and radio module **140**, **142** without the GPS receiver **136**.

For example, referring specifically to FIG. 2, the large expansion pack **134'** may be fitted with a GPS receiver **136** and a cell modem **140**, with GPS receiver **136** and a radio module **142**, or with all three components **136**, **140**, and **142** as shown.

Additional components of pack **134'** may include a base **146**, e.g., fabricated from a suitable plastic or metallic material, a printed circuit board assembly **148**, e.g., having circuitry communicably couple the modules **136**, **140**, **142** to one another and to the data collector **102** (FIG. 1). Other components may include a cover **150**, e.g., plastic or metallic, one or more gasket(s) **152** to form a weather-tight seal between the base **146** and cover **150**, and various mounting/connecting hardware such as shown at **154**.

As shown, the cell modem **140** may be supported by the printed circuit board **148**, while the GPS receiver **136** and radio **142** may be supported by a carrier board **156**. The carrier board may include electronic circuitry to power one or more of the modules (e.g., to convert the 5 volt power supplied by circuit board **148** to the 3.3 volts required by particular examples of the GPS and radio modules **136**, **142**) and to control power up and/or sleep mode states. Pack **124'** may also include an internally mounted antenna (not shown) for any of the modules, e.g., the cell and radio modules **140**, **142**, and/or antenna connectors for externally mounted antennae (e.g., for GPS module **136**).

It is also noted that in particular embodiments, as mentioned above, GPS board **136** may include a multi-frequency device, having the capability to use other systems such as the GLONASS system or terrestrial systems, etc., in addition to the aforementioned GPS system. It should also be recognized that cellular module **140** may be configured to operate on substantially any cellular protocols, such as both GSM and CDMA, etc.

Turning now to FIG. 3, the small expansion pack **134''** is substantially similar to the large expansion pack, but may be sized, shaped and otherwise configured to include any two of the three modules **136**, **140**, **142**. In the particular embodiment shown, radio module **142** includes any of at least three different radio modules, e.g., those commercially available from Maxstream, Futaba, or Cirronet. Pack **134''** also includes a cell module **140** as shown. If desired, either of these modules **140**, **142** may be replaced with a GPS module **136** (FIG. 2).

Additional components may be as shown and described hereinabove with respect to pack **134'**, including base **146'**, printed circuit board assembly **148'**, gasket(s) **152'**, cover **150'**, and various mounting hardware **154'**.

In addition to the aspects discussed hereinabove, embodiments of the present invention may include various additional features such as additional serial ports, USB ports, 12 Volt DC input port, camera, and wireless networking modules (e.g., Bluetooth and/or 802.11x). It is also anticipated that the expansion packs may be modular, and installed and removed by end-users, e.g., using a common tool such as a coin or screwdriver, using quarter-turn screws or the like. A conventional snap-in mount may also be used.

Non-limiting examples of Radio Modems, GPS Boards, and Cellular Modems that may be used in embodiments of the invention are shown in the following Table 1:

TABLE I

Radios	
	Maxstream 9XTend 900 mHz Spread Spectrum Radio (MMCX), Maxstream 24XStream 2.4 GHz Spread Spectrum Radio (MMCX), Maxstream Xbee-Pro 2.4 Ghz Zig Bee Module, Cirronet Wit2410 2.4 GHz Spread Spectrum Module, Cirronet Wit2450 2.4 GHz Spread Spectrum Module, Cirronet Wit2411 2.4 GHz Spread Spectrum Module, Satel 3as ~460-480 mHz range.
GPS Boards	
	Novatel (www.novatel.com) OEMV-2 L1, L2 GPS, Novatel OEMV-3 72 channel GPS.
Cellular Modems	
	Sierra Wireless (www.sierrawireless.com) MC8775 Cellular Modem Siemens https://pia.khe.siemens.com/index14625.htm HC15, HC25 HDSPA Cellular Modem Novatel Wireless Expedite Cellular Modems Enfora (www.enfora.com) Enabler IIIG Quad band GSM/GPRS cellular modem Wavecom Embedded.net (www.embedded.net)

A method of fabricating a self-contained, hand-held, wireless engineering survey data collection system will now be described as illustrated by the flow chart of FIG. 4. As shown, the method **400** commences with providing **410** a survey data collector substantially as shown and described hereinabove with respect to FIGS. 1B-3. At **412**, a survey-grade GPS module is supported with the housing and configured to be communicably coupled to the processor, the GPS module being configured for positioning accuracy within a margin of error of 3 cm. At **414**, a GPS antenna port is supported with the housing and configured to be communicably coupleable to the GPS module. At **416**, the survey data collector is configured to capture engineering survey data including position data generated by the GPS module.

In summary, it will be appreciated that the above described embodiments provide a convenient vehicle for capturing engineering survey/position data, including precision position data in real-time, using a convenient hand-held, wireless device capable of multiple means of wireless connectivity.

Turning to FIG. 5, an alternate aspect of the present invention is shown as engineering survey data collection system **100'**. System **100'** is substantially similar to system **100** shown and described hereinabove with respect to FIG. 1B, with the exception of differences which are discussed hereinbelow. Notably, system **100'** is disposed within a housing **104'** having a hand-held, tablet, form factor as shown. As with system **100** described above, system **100'** includes a user interface including input and output devices supported by the housing and communicably coupled to the processor **106**. In particular aspects, the user interface includes a screen **114'**, which may take the form of a touchscreen configured for enabling both input and output. Screen **114'** may be substantially similar to, though larger than, screen **114** of system **100**.

In addition to keypads **120** and **122** (FIG. 1B) displayed on demand by the screen **114'**, the user interface may include any number of additional optional elements such as a navigation pad **124'** and/or dedicated function keys **126'**.

In the various embodiments described herein, including any of the optional variations thereof, the housing **104'** may be water and dust resistant to NEMA (National Association of Electrical Manufacturers) IP65 standards, while also being

ruggedized to meet one or more of the test methods of United States Military Standard MIL-STD-810G (U.S. Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests), pertaining to Environmental Conditions including Operating and Storage Temperatures, Vibration, Drop/Shock, Sand & Dust, Water, and Humidity.

In particular aspects, system **100'** may include a modular expansion pack **134**, **134'**, **134"**, etc., supported by the housing and communicably couplable to the processor **106**, such as shown and described with respect to FIG. **1B** hereinabove. However, in the aspect shown in FIG. **5**, a survey-grade GNSS (e.g., GPS) receiver **136**, e.g., configured for positioning accuracy within a margin of error of 3 cm or less, may be disposed within housing **104'**, without the need for an expansion pack. In particular embodiments, receiver **136** may provide an accuracy of 1 cm or less horizontally, and 2 cm or less vertically, e.g., using the OEM615™ GNSS receiver board from Novatel Inc. (Calgary, Alberta, CA). In some variations, system **100'** may include a GPS antenna port **138** (FIG. **1B**) supported by the housing and communicably couplable to the GPS receiver **136**, for connection to a conventional external GPS antenna (not shown). However, in particular aspects, such as shown in FIG. **5**, system **100'** may be provided with an antenna-less housing **104'** (e.g., supporting an internal GNSS antenna), to simplify use in the field and provide the housing **104'** with enhanced resistance to environmental incursions. Thus, in particular applications, system **100'** is capable of providing desired positioning accuracy using only an internal GNSS antenna.

In particular aspects, housing **104'** may also be provided with cellular transceiver **140**, such as to provide the data collector **102** with Internet connectivity and/or wireless voice communication. In addition, housing **104'** may be provided with point-to-point audio transceiver **142**, such as a spread spectrum audio transceiver to permit wireless radio communication in areas not covered by cellular networks.

System **100'** thus provides a self-contained, hand-held, wireless engineering survey data collection system in the form of an industry hardened tablet computer. This approach provides a unique combination of GNSS (GPS), computer, software, and multiple channel communication, in a hand-held tablet form factor, while providing substantially the same GPS performance accuracy as other larger scale single-function survey-grade GPS receivers. Moreover, contrary to conventional wisdom for handheld devices designed primarily for outdoor use, system **100'** runs a full computer (i.e., desktop) operating system (e.g., Microsoft Windows 7™, available from Microsoft Corporation, Redmond, Wash.), or substantially any other full operating system such as the OS X (Apple, Inc., Cupertino, Calif.), or Linux operating system. Thus, as used herein, the terms "full operating system" and "desktop operating system" are used interchangeably with one another and consistently with the conventional definition of "desktop operating system" (desktop OS), to refer to the control program in a user's desktop or laptop computer. See, for example, the definition for desktop operating system at pcmag.com/encyclopedia. Moreover, this definition specifically excludes conventional mobile operating systems (mobile OS) which are built exclusively for mobile devices such as smartphones, personal digital assistants (PDAs), tablets or other embedded mobile OS, which are similar to desktop OS (such as the aforementioned Windows, Linux, and OS X) but are relatively simple and light and configured to primarily manage the wireless variations of local and broadband connections, mobile multimedia and various input methods.

Examples of popular mobile operating systems are Android, Symbian, iOS, BlackBerry OS and Windows Mobile. See, for example, the definition for mobile operating system at techopedia.com.

One particular example of system **100'** includes the ruggedized hand-held tablet computer known as the Carlson Supervisor™ RTK GNSS Survey System, commercially available from Carlson Software, Inc., of Maysville, Ky., which provides an integrated, high accuracy survey grade RTK GNSS receiver and ultra mobile ruggedized Windows tablet PC. By combining a sunlight viewable touch screen ultra mobile ruggedized tablet PC with a high accuracy survey grade RTK GNSS receiver a user may collect survey grade measurements directly into a Windows PC operating system environment. The combination of these components as shown and described above, including the full operating system environment, enables mapping professionals to access the full computing power of a PC environment while in the field, collecting survey grade measurements.

Those skilled in the art will recognize that at the time of the instant invention, power consumption in mobile devices was a primary concern. It would therefore have been counterintuitive to use anything in a mobile device that would have been viewed as increasing power consumption relative to available alternatives. This would have been particularly true in the case of mobile, high accuracy survey grade GNSS devices, due to the relatively high power consumption of survey grade GNSS receivers. Those skilled in the art therefore would not have used a full operating system (OS) in a handheld with GNSS, but would have instead recognized that significant energy savings may be provided by using lighter, mobile operating systems such as Windows CE™, etc. The skilled artisan would have recognized that the power consumption issue would have been further exacerbated by the tablet form factor, due to the power needed to provide the tablet touchscreen with sufficient illumination as to be viewable outdoors, e.g., in direct sunlight. And as discussed hereinabove, it was counterintuitive to incorporate a GNSS board into a handheld form factor since industry standard was to use large pole with GNSS antenna at the top for accuracy. It would not have been expected that the 3-cm accuracy provided by the embodiments hereof, could have been achieved without a pole mounted external antenna, or with only the internal antenna of system **100'**. The instant embodiments overcame these obstacles, to enable surveyors and engineers to perform surveying activities with a portable tablet that leverages full OS capabilities in the field, e.g., to enable online remote access for technical support, online bug fixes, online configuration, etc.

The following Tables II-IV include illustrative examples of certain aspects of the present invention, and are not intended to limit the present invention to any one particular aspect or set of features.

TABLE II

RTK GNSS Windows Ultra Mobile Rugged Tablet

large data collector screen - 7"
fast data collector processor - 1.6 Ghz
Large memory - storage 64 Gb, RAM 2 Gb
Industry leading data collection software Carlson SurvPC
Novatel OEM615 GNSS receiver
Windows 7 Ultimate Operating System

US 9,188,440 B2

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TABLE II-continued

RTK GNSS Windows Ultra Mobile Rugged Tablet
Bluetooth, Wifi, Cellular (cdma & gsm), 2 usb, 9 pin Serial, and Ethernet capable
Dual Hot Swappable Batteries
2 Megapixel camera with LED

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TABLE II-continued

RTK GNSS Windows Ultra Mobile Rugged Tablet
Only 2.42 lbs
Upgradable from L1 GNSS GIS to full RTK GNSS

TABLE III

Supervisor Tablet Specifications	
Size	5.56" (144 mm) × 9.5" (242 mm) × 1.57" (40 mm)
Weight	1.1 kg (2.42 lb)
Environment	
Operating:	−9.4° F. to 140° F. (−23° C. to 60° C.), MIL-STD-810G, Method 501.4 Procedure II, MIL-STD 810G, Method 502.4, Procedure I, II, III
Storage:	−40° F. to 158° F. (−40° C. to 70° C.) MIL-STD-810G, Method 501.4 Procedure II, MIL-STD 810G, Method 502.4, Procedure I, II, III
Drop:	MIL-STD-810G 4 ft Drop, Free to Concrete. 26 drops from 4 ft (1.22 m) MIL-STD-810G, Method 516.5, Procedure IV
Vibration:	MIL-STD-810G, Method 514.5 Procedures I & II, General minimum integrity and the more rigorous loose cargo test
Sand & Dust:	IP 65, MIL-STD-810G
Water:	IP 65, MIL-STD-810G
Humidity:	MIL-STD-810G, Method 507.4, 90% RH temp cycle 0° C./70° C.
Altitude:	15,000 ft (4572 m) at 73° F. (22° C.)
Processor/Memory	Intel Ultra Low Power Atom 2530 1.6 GHz processor (w/US15W Chipset), 2 GB DDR2 RAM
Data Storage/Disk	64 GB SSD solid state hard drive
Operating System	Microsoft Windows 7 Ultimate
Screen	7" widescreen 1024 × 600 resolution TRT LCD, MaxView™ sunlight readable resistive touchscreen display
Keyboard	10 keys: Power key Menu key (Controls Brightness, Volume, Battery Status, WiFi & BT On/Off, and 3G On/Off) 4 + 1 Navigation/Directional keys (Left, Right, Up, Down, Center for Enter) 3 × User programmable hotkey buttons that control up to 6 functions On-screen QWERTY soft keyboard
Battery	Hot-swappable Dual Li-Polymer Battery Pack, 2600 mAh each, support minimum 6 hours operation
Connections	2 × USB 2.0 port (one fully waterproof, even when the latch is open) 1 × 9-pin serial RS-232 port fully waterproof, even when the latch is open 1 × LAN 1 × DC power port Input: 120-240 VAC, 50-80 Hz, 12 VOC Output Docking Connector (Contact Pin Type) 1 × 4 Pin docking Audio Out 1 × Microphone Audio integrated (one speaker) Fully Gobi™ 2000 PCIe module-ready
Communication	Wireless LAN 802.11b/g/n PAN: Integrated Bluetooth v.2.0 + EDR Compliant WWAN (Optional) Gobi™ 2000 ready, supporting the following RF bands: Quad-band EDGE/GPRS/GSM - 850/900/1800/1900 MHz Dual-band Ev-DO/COMA - 800/1900 MHz
Navigation	u-blox GPS, WAAS/EGNOS capable
Camera	2 Megapixel Camera + LED light
Options	12 V vehicle charger, Pole mount solution, Vehicle cradle that includes: *1 × DC PWR *2 × USB *2 × RS232 *1 × 10/100LAN *VESA holes

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TABLE IV

Supervisor GPS Specifications		
Performance ¹		
Channel Configuration		
120 Channels ²		
Signal Tracking		
GPS: L1, L2, L2C		
GLONASS: L1, L2		
Galileo: E1		
GIOVE-A/GIOVE-B (test)		
Compass ³		
SBAS		
Horizontal Position Accuracy (RMS)		
Single Point L1	1.5 m	
Single Point L1/L2	1.2 m	
SBAS ⁴	0.6 m	
DGPS	0.4 m	
RT-20 ⁵	0.2 m	
RT-2™	1 cm + 1 ppm	
Initialization time	<10 s	
Initialization reliability	>99.9%	
Measurement Precision (RMS)		
Fully independent code and carrier measurements:		
	GPS	GLO
L1 C/A Code	4 cm	8 cm
L1 Carrier Phase	0.5 mm	1 mm
L2 P(Y) Code ⁶	8 cm	8 cm
L2 Carrier Phase ⁶	1 mm	1 mm
L2C code ⁷	8 cm	8 cm
L2C carrier phase ⁷	0.5 mm	0.5 mm
Data Rate ⁸		
Measurements	up to 50 Hz	
Position	up to 50 Hz	
Time to First Fix		
Cold Start ⁹	<50 s	
Hot Start ¹⁰	<35 s	
Signal Reacquisition		
L1	<0.5 s (typical)	
L2	<1.0 s (typical)	
Time Accuracy ¹¹		
Time Accuracy ¹¹	20 ns RMS	
Velocity Accuracy		
Velocity Accuracy	0.03 m/s RMS	
Velocity Limit ¹²		
Velocity Limit ¹²	515 m/s	
Physical and Electrical		
Dimensions	46 × 71 × 11 mm	
Weight	24 g	
Power		
Input Voltage	+3.3 VDC [+/- 5%]	
Power Consumption ¹³	1 W	
Antenna LNA Power Output		
Output Voltage	5.0 VDC	
Maximum Current	100 mA	
Connectors		
Main 20-pin dual row male header		
Antenna Input MCX female		
Communication Ports		
3 LV-TTL up to 921,600 bps		
2 CAN Bus ¹⁴ 1 Mbps		
1 USB 12 Mbps		
Environmental		
Temperature		
Operating	-40° C. to +85° C.	
Storage	-55° C. to +95° C.	
Humidity	95% non-condensing	

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TABLE IV-continued

Supervisor GPS Specifications	
Vibration Temperature	
Random Vibe	MIL-STD 810G (7.7 g RMS)
Sine Vibe	IEC60068-2-6 (5 g)
Bump	ISO9022-31-06
Shock	MIL-STD-810G (40 g)
Features	
Field-upgradeable software	
PAC multipath mitigating technology	
Differential GPS positioning	
Differential correction support for RTCM 2.1, 2.3, 3.0, 3.1, CMR, CMR+ and RTCA	
Navigation output support for NMEA-0183 and detailed NovAtel ASCII and binary logs	
Auxiliary strobe signals, including a configurable PPS output for time synchronization and mark inputs	
Outputs to drive external LEDs	
GLIDE smoothing algorithm	
Optional Accessories	
GPS-700 series antennas	
ANT series antennas	
RF Cables - 5 and 10 m lengths	
Development Kit	
Firmware Options	
RT-2	RT2-L1TE
RT-20	RAIM
ALIGN	

¹Typical values. Performance specifications subject to GPS system characteristics, US DOD operational degradation, ionospheric and tropospheric conditions, satellite geometry, base-line length, multipath effects and the presence of intentional or unintentional interference sources.

²Tracks up to 60 L1/L2 satellites.

³The Compass signal is not finalized and changes in the signal structure may still occur.

⁴Designed for Compass Phase 3 compatibility.

⁵GPS only.

⁶Expected accuracy after static convergence.

⁷L2 P for GLONASS.

⁸L2 C/A for GLONASS.

⁹50 Hz while tracking up to 20 satellites.

¹⁰Typical value. No almanac or ephemerides and no approximate position or time.

¹¹Typical value. Almanac and recent ephemerides saved and approximate position and time entered.

¹²Time accuracy does not include biases due to RF or antenna delay.

¹³Export licensing restricts operation to a maximum of 515 metres per second.

¹⁴Power consumption values for GPS L1/L2

¹⁵User application software required.

FIG. 6 shows a diagrammatic representation of a machine such as usable in system 100, in the exemplary form of a computer system 300 within which a set of instructions for causing the machine to perform any one of the methodologies discussed above, may be executed. In alternative embodiments, the machine may include a Personal Digital Assistant (PDA), a cellular telephone, a web appliance or any machine configured in accordance with the teachings of the present invention, and capable of executing a sequence of instructions that specify actions to be taken by that machine.

The computer system 300 includes a processor 302, a main memory 304 and a static memory 306, which communicate with each other via a bus 308. The computer system 300 may further include a video display unit 310 (e.g., a liquid crystal display (LCD), plasma, cathode ray tube (CRT), etc.). The computer system 300 may also include an alpha-numeric input device 312 (e.g., a keyboard or touchscreen), a cursor control device 314 (e.g., a mouse), a drive (e.g., disk, flash memory, etc.) unit 316, a signal generation device 320 (e.g., a speaker) and a network interface device 322.

The drive unit 316 includes a computer-readable medium 324 on which is stored a set of instructions (i.e., software) 326

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embodying any one, or all, of the methodologies described above. The software 326 is also shown to reside, completely or at least partially, within the main memory 304 and/or within the processor 302. The software 326 may further be transmitted or received via the network interface device 322. For the purposes of this specification, the term “computer-readable medium” shall be taken to include any medium that is capable of storing or encoding a sequence of instructions for execution by the computer and that cause the computer to perform any one of the methodologies of the present invention. The term “computer-readable medium” shall accordingly be taken to include, but not be limited to, solid-state memories, optical and magnetic disks, and carrier wave signals.

Thus, a method and apparatus in accordance with the present invention have been described. Although the present invention has been described with reference to specific exemplary embodiments, it will be evident that various modifications and changes may be made to these embodiments without departing from the broader spirit and scope of the invention. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense.

Furthermore, embodiments of the present invention include a computer program code-based product, which includes a computer readable storage medium having program code stored therein which can be used to instruct a computer to perform any of the functions, methods and/or modules associated with the present invention. The computer storage medium includes any of, but not limited to, the following: CD-ROM, DVD, magnetic tape, optical disc, hard drive, floppy disk, ferroelectric memory, flash memory, ferromagnetic memory, optical storage, charge coupled devices, magnetic or optical cards, smart cards, EEPROM, EPROM, RAM, ROM, DRAM, SRAM, SDRAM, and/or any other appropriate static or dynamic non-transitory memory or data storage devices.

It should be noted that the various modules and other components of the embodiments discussed hereinabove may be configured as hardware, as computer readable code stored in any suitable computer usable medium, such as ROM, RAM, flash memory, phase-change memory, magnetic disks, etc., and/or as combinations thereof, without departing from the scope of the present invention.

It should be further understood that any of the features described with respect to one of the embodiments described herein may be similarly applied to any of the other embodiments described herein without departing from the scope of the present invention.

In the preceding specification, the invention has been described with reference to specific exemplary embodiments for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of this disclosure. It is intended that the scope of the invention be limited not by this detailed description, but rather by the claims appended hereto.

The above systems are implemented in various computing environments. For example, particular embodiments or portions thereof may be implemented on a conventional IBM PC or equivalent, multi-nodal system (e.g., LAN) or networking system (e.g., Internet, WWW, wireless web). All programming and data related thereto are stored in computer memory, static or dynamic or non-volatile, and may be retrieved by the user in any of: conventional computer storage, display (e.g., CRT, flat panel LCD, plasma, etc.) and/or hardcopy (i.e., printed) formats. The programming of the present invention

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may be implemented by one skilled in the art of computer systems and/or software design.

Having thus described the invention, what is claimed is:

1. A self-contained, hand-held, wireless engineering survey data collection system, comprising:
 - a survey data collector including:
 - a housing having a hand-held, tablet, form factor;
 - a processor, memory module, data storage, and power source disposed within the housing;
 - a full personal computer operating system;
 - a user interface including input and output devices supported by the housing and communicably coupled to the processor;
 - the user interface including a sunlight viewable touch screen;
 - a survey module including computer readable instructions disposed in a non-transitory computer readable medium, for configuring the processor, memory module, data storage, and user interface to capture and store engineering survey data;
 - a plurality of communications ports configured for communicating with peripheral devices;
 - a survey-grade GNSS (Global Navigation Satellite System) module disposed within the housing and communicably coupled to the processor, the GNSS module configured for positioning accuracy within a margin of error of 3 cm;
 - an internal GNSS antenna supported within the housing in operative engagement with the GNSS module;
 - the housing being ruggedized to at least MIL-STD-810G (U.S. Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests);
 - wherein the survey data collector is configured to capture engineering survey data including position data generated by the GNSS module.
2. The self-contained, hand-held, wireless engineering survey data collection system of claim 1, wherein the GNSS module is configured for positioning accuracy within a margin of error of 1 cm vertically and 2 cm horizontally.
3. The self-contained, hand-held, wireless engineering survey data collection system of claim 1, wherein the survey data collector is ruggedized to at least MIL-STD-810G for one or more environmental conditions selected from the group of Operating and Storage Temperatures, Vibration, Drop/Shock, Sand & Dust, Water, Humidity, and combinations thereof.
4. The self-contained, hand-held, wireless engineering survey data collection system of claim 3, wherein the survey data collector is ruggedized to at least MIL-STD-810G for each of Operating and Storage Temperatures, Vibration, Drop/Shock, Sand & Dust, Water, and Humidity.
5. The self-contained, hand-held, wireless engineering survey data collection system of claim 1, being water and dust resistant to NEMA (National Association of Electrical Manufacturers) IP65 standards.
6. The self-contained, hand-held, wireless engineering survey data collection system of claim 1, wherein the GNSS module comprises a dual frequency GNSS receiver.
7. The self-contained, hand-held, wireless engineering survey data collection system of claim 6, wherein the personal computer operating system comprises an operating system configured for at least x86 and x86-64 microprocessors.
8. The self-contained, hand-held, wireless engineering survey data collection system of claim 7, further comprising a cellular transceiver.

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9. The self-contained, hand-held, wireless engineering survey data collection system of claim 8, further comprising a spread spectrum audio transceiver.

10. The self-contained, hand-held, wireless engineering survey data collection system of claim 1, wherein the plurality of communications ports include wireless communications ports.

11. The self-contained, hand-held, wireless engineering survey data collection system of claim 10, wherein the wireless communications ports are selected from the group consisting of Bluetooth and WiFi (802.11x) enabled ports.

12. The self-contained, hand-held, wireless engineering survey data collection system of claim 1, wherein the user interface comprises an input device configured for operation with a gloved hand.

13. The self-contained, hand-held, wireless engineering survey data collection system of claim 12, wherein the user interface comprises a navigation pad and a touchscreen.

14. The self-contained, hand-held, wireless engineering survey data collection system of claim 13, wherein the housing comprises a tripod hook.

15. A method of fabricating a self-contained, hand-held, wireless engineering survey data collection system, comprising:

- (a) configuring a housing having a hand-held, tablet form factor;
 - (b) disposing a processor, memory module, data storage, and power source within the housing;
 - (c) operatively engaging a full personal computer operating system with the processor, memory module, data storage and power source;
 - (d) supporting a user interface including input and output devices, with the housing, and communicably coupling the user interface to the processor;
 - (e) configuring the user interface to include a sunlight viewable touch screen;
 - (f) providing a survey module including computer readable instructions disposed in a non-transitory computer readable medium, for configuring the processor, memory module, data storage, and user interface to capture and store engineering survey data;
 - (g) configuring a plurality of communications ports for communicating with peripheral devices;
 - (h) disposing a survey-grade GNSS (Global Navigation Satellite System) module within the housing and communicably coupling the GNSS module to the processor, the GNSS module being configured for positioning accuracy within a margin of error of 3 cm; and
 - (i) supporting a GNSS antenna within the housing in operative engagement with the GNSS module; and
 - (h) ruggedizing the housing to at least MIL-STD-810G (U.S. Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests);
- wherein the survey data collector is configured to capture engineering survey data including position data generated by the GNSS module.

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16. The method of claim 15, wherein said disposing (b) further comprises the GNSS module being configured for positioning accuracy within a margin of error of 1 cm vertically and 2 cm horizontally.

17. The method of claim 15, comprising ruggedizing the survey data collector to at least MIL-STD-810G for one or more environmental conditions selected from the group of Operating and Storage Temperatures, Vibration, Drop/Shock, Sand & Dust, Water, Humidity, and combinations thereof.

18. The method of claim 17, further comprising ruggedizing the survey data collector to at least MIL-STD-810G for each of Operating and Storage Temperatures, Vibration, Drop/Shock, Sand & Dust, Water, and Humidity.

19. The method of claim 15, comprising configuring the housing for water and dust resistance to NEMA (National Association of Electrical Manufacturers) IP65 standards.

20. A self-contained, hand-held, wireless engineering survey data collection system, comprising:

- a survey data collector including:
 - a housing having a hand-held, tablet, form factor;
 - a processor, memory module, data storage, and power source disposed within the housing;
 - a full personal computer operating system;
 - a user interface including input and output devices supported by the housing and communicably coupled to the processor;
 - the user interface including a sunlight viewable touch screen;
 - a survey module including computer readable instructions disposed in a non-transitory computer readable medium, for configuring the processor, memory module, data storage, and user interface to capture and store engineering survey data;
 - a plurality of communications ports configured for communicating with peripheral devices;
 - a survey-grade GNSS (Global Navigation Satellite System) module disposed within the housing and communicably coupled to the processor, the GNSS module configured for positioning accuracy within a margin of error of 3 cm;
 - an internal GNSS antenna supported within the housing in operative engagement with the GNSS module;
 - the survey data collector being ruggedized to at least MIL-STD-810G (U.S. Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests) for each of Operating and Storage Temperatures, Vibration, Drop/Shock, Sand & Dust, Water, and Humidity;
 - the survey data collector being water and dust resistant to NEMA (National Association of Electrical Manufacturers) IP65 standards;
 - wherein the survey data collector is configured to capture engineering survey data including position data generated by the GNSS module.

* * * * *